# CURRENT STATUS OF METRIC REDUCTION OF (PASSIVE) SCANNER DATA

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ABSTRACT:

General discussion of extraction of metric information from scanner (particularly multispectral) data is presented. Consideration is given to: data from both aircraft and spacecraft; singly scanned areas and areas with multiple coverage; various mathematical models used up to the present time; and published numerical results. Future trends are also discussed.

## 1. INTRODUCTION:

The emphasis in this paper is on the results from passive sensor (particularly multispectral scanner) data, because another invited paper is given in this Congress on active sensor data. It follows the excellent account by Konecny ( 12) on the geometric restitution of remote sensing data where mathematical models, procedures, and numerical results obtained by 1976 were given. For ease in presentation, one section briefly describes all models used. Then, a separate section is devoted to the applications with satellite and aircraft data. Another section discusses multiseries data.

## 2. BASIC MATHEMATICAL MODELS

In the metric reduction of digital image scanner data, a mathematical model is used to represent the platform/sensor imaging characteristics. All the published models can be classified into essentially two groups. In the first group, a parametric model based on the well known collinearity condition is used. On the other hand, the second group includes all models which are interpolative in nature. Each of these groups, with its individual modeling process, is discussed in a separate section.

### 2.1 Parametric Models

The basis for these models is the collinearity condition that the center point of an image element or pixel, the point representing the instantaneous projection center, and the center point of the corresponding terrain resolution element, all lie on a straight line. In addition to the pixel locations (corresponding to image coordinates) and the object point coordinates, the collinearity equations usually contain six elements of exterior orientation. Theoretically, because the platform is continuously moving, there are six elements for each pixel (assuming a scanner). However, because of the relatively short time period of scanning one line of imagery, it is common to consider only one set of six elements for each line (which makes it equivalent to linear array scans). And even with this assumption, it is easily seen that there would be an excesive number of exterior orientation elements for any significant number of image lines. Since these elements are almost always unknown a more practical approach is used.

For each element, some function is used to mathematically model its' behavior trend. Thus, for one element, the function selected represents its variation with time, or equivalently with the "line" number in the digital image. (The line number is used in a manner similar to the use of x image coordinate in a frame photograph.)

The six elements of exterior orientation are $X_c$, $Y_c$, $Z_c$, which are positional, and $\omega,\phi,\kappa$ which are rotational. While these elements are stochastically uncorrelated in the frame photography case, there are very high correlations in scanner imagery between the $\omega$ and $Y_c$ parameters and $\phi$ and $Y_c$ parameters. In order to deal with the correlation between $\omega$ and $Y_c$, most scanners are roll stabilized, thus constraining $\omega$ to zero. Another possible solution for aircraft scanner imagery is the use of sidelapping data sets, in order to make $\omega$ recoverable. The ability to recover both $\phi$ and $X_c$ is directly dependent on the terrain relief relative to the height of the scanner above the terrain. The greater the relief differences, the lower the correlation. Another possibility is to record the values of $\omega,\phi$, $X_c$, or $Y_c$ in flight, then apply these values during the geometric processing. However, the most common procedure is to constrain both $\omega$ and $\phi$ to zero during the adjustment and make no attempt to recover their values.

### 2.1.1 Orbit Modeling For Images From Spacecraft

Perhaps the most direct method for functionally expressing the exterior orientation elements for spacecraft images is to model the vehicle motion by ideal orbit parameters. Bähr (1,2) recommended the use of the six parameters of the orbit: semi-major axis, a; eccentricity, e; inclination of orbital plane, i; right ascension of ascending node $\Omega$; mean anomaly, $M_T$; and the argument of perigee $\omega_T$. If these parameters are known, then the satellite position $\phi,\lambda,r$ as well as nominal heading $\beta_n$ can be calculated as functions of time. Ground points are then related to the image points using the collinearity equations. In these, while the rotational elements ($\omega,\phi,\kappa$) of exterior orientation appear, the positional elements are now replaced by functions of the orbital parameters. Small angle approximations are used for $\omega, \phi, \kappa$ thus avoiding their trigonometric functions.

A futher improvement over the orbital modeling is effected by Rifman et al (5,22), where a linear sequential estimator, or a Kalman filter, is developed. It is used to estimate a 13 component state vector from ground control points. Twelve of theses components are the coefficients of cubic polynomials in time for the sensor attitude, and one component is for attitude bias. This sequential estimation scheme offers several advantages: (a) fewer numbers of ground control points are required to achieve a given performance level; (b) search areas for ground control points become smaller in size with each state vector update, permitting more rapid location of each successive point; (c) sequential editing of control points is possible without having to process all control points first, thus control points can be redefined or deleted as part of the editing process.

### 2.1.2 Vehicle/Sensor Modeling By Polynomials

Each of the six exterior orientation elements can be represented by a polynomial of a suitable order (3,9). The selected polynomial would apply to a segment of imagery with the corresponding set of coefficients. Another set of coefficients would be calculated for the second image segment, and so on. The degree of the polynomial depends, among other things, upon the length of the segments. One possibility is to take long segments with higher order polynomials; another is shorter segments with linear polynomials. The latter case seems to work better, at least for aircraft MSS data ( 9 ).

The best application of the polynomial modeling is to replace the highly non-linear collinearity equations by their differential, and thus linear, form. Then the change in each element carried, (e.g. $dY_c$, $d\phi$, etc.) is written as a polynomial in the image x-coordinate (which is essentially equivalent to time). After substitution of these polynomials into the pair of differential formulas and reduction two equations are obtained, one for X and the other for Y coordinates of the object point. When several image sections are used at the same time, constraint equations are written at the section joints to guarantee uniqueness of the object coordinates.

### 2.1.3 Sensor Modeling Using Harmonics

An alternative to using polynomials is to use Fourier series expansion for each of the exterior orientation elements. The sine and cosine functions are usually in terms of ratios of the image coordinates and an equivalent of a constant time interval which is appropriately chosen for the frequency of the given data. The linearization of the harmonic equations requires a somewhat different procedure than that used for the case of polynomials (12 ).

### 2.1.4 Autoregressive Model For Sensor

All the models discussed so far make use of a deterministic model by writing specific functions to represent the behavior of the exterior orientation elements. Another alternative is to regard such behavior as stochastic rather than deterministic and employ an autoregressive model for the purpose. Of the many possible autoregressive processes, the Gauss-Markov, both first and second order, have been suggested ( 7 ) and applied to aircraft MSS data ( 8,9,10,11,14,15).

A Gauss-Markov process is based on the Markovian assumption that the value of the process at any time depends only on the previous one or two values, depending on whether a first or second order process is assumed. Equations relating the orientation parameters of each line to those of the one or two preceeding lines are used to model the sensor behavior. Control point information is included by the use of the differential collinearity equations.

## 2.2 Interpolative Models

In the procedures employing these models no attempt is made to model the sensor/platform behavior, as in the case of using the collinearity conditions in the parametric approach. Instead, some function or relationship is selected between the X,Y coordinates in the object space and x,y (or row, column) in the image space, and assumed to represent the mapping from one space to the other. There are two groups of methods: one in which a general transformation is used for the entire image record (or segment thereof), and the other in which a different function is used for each point to be interpolated. Each of these will be discussed separately.

### 2.2.1 Interpolation Methods Using General Transformation:

The group of procedures here employ a pair of functions (one for X, and one for Y) which holds for all points in the image. This means that the numerical values of the coefficients in the equations are the same for each of the points of interest in the image. By image we mean one segment or record. Thus, if we are working with only one omage segment, there will be only one set of transformation coefficients. However, if there are more image segments (in other words, if the image record is segmented into several sections), each section will have a set of coefficients with different numerical values. It is usually advisable to enforce constraints at the borders between successive segments.

The transformations used include the following: (1) Four-parameter transformation which is also called two-dimensional linear conformal, Helmert, or similarity transformation; it represents a uniform scale change, a rotation between XY and xy axes, and two shifts.
(2) Six-parameter or affine transformation, which includes two scale changes, one rotation, skewness or non-perpendicularity of the axes, and two shifts. (3) Eight-parameter projective transformation, which represents a rotation and two shifts in each of the two planes (XY and xy), and a tilt between the planes which is combined with scale to produce a continuously changing scale along lines of maximum tilt.
(4) General polynomials of varying degrees; these are usually of higher than the first order (which would be the four-or six-parameter transformation.) The choice of degree depends on the length of the image segment.

2.2.2.1 Weighted Mean

For this technique, a weight function is selected which is inversely proportional to a function of the distance between the point to be interpolated and other reference points. Thus, the closer is a reference point the more is its contribution to the interpolated value, and vice versa. At any point of interest, the required vector (usually calculated in two components) is obtained as the weighted mean of all vectors at reference points surrounding the point. The choice of the weight effectively determines the limit of the region within which reference points are used to estimate at the central point of the region.

2.2.2.2 Moving Averages

This is a generalization of the weighted mean procedure which allows greater flexibility in point interpolation. The x- and y-components of the interpolated vector at a point are written as functions of the coordinates of reference points surrounding the point. Six-parameter affine equations, or second order polynomials may be used for the purpose. Usually a sufficient number of reference points is used to yield an over determination, and the coefficients of the functions are estimated by weighted least squares. As before, the weights are evaluated from a function with the distance between the points in question and reference points as the argument. Once these coefficients are calculated, they are substituted back into the function to compute the desired value. It is important to note that a new set of coefficients must be calculated for each point to be interpolated. This usually makes the procedure computationally time consuming. Finally, it can be seen than when the selected functions are truncated down to only the zero order terms the procedure reduces to the weighted mean.

2.2.2.3 Meshwise Linear

In this method, the reference points are connected into adjacent or contiguous meshes such as triangles or quadrilaterals. The reference points forming the mesh that includes the point to be interpolated are used for the purpose. Usually a six-parameter affine transformation is used. The method is computationally efficient within each mesh, but the formation of the meshes may be time consuming. Also, unless a severe condition is placed on the reference points, the solution for points on the boundary of the image may not be accurate due to extrapolation.

2.2.2.4 Linear Least Squares Prediction

This method treats the vectors at the reference points as a random field. The covariance function assiciated with this field is either assumed a prior, or its shape is assumed and the numerical parameters calculated from the data ( 13 ). As applied, both stationarity and isotropy of the field are also assumed. This may be true for some data (e.g. Satellite MSS) but not for other (e.g. aircraft MSS). From the covariance function, the autocovariance matrix for data at the reference points is evaluated. Also, the cross-covariance matrix (or vector) between the point to be interpolated and the reference points is also needed. These, and the data vector at the reference points are used to calculate the value at the point of interest. This calculated value can be obtained using the reference point data directly, or filtering the data for a known error porportion.

The amount of filtering can also be selected.

## 3. APPLICATIONS TO SPACECRAFT DATA

The most widely used spacecraft data is that obtained from the LANDSAT series of satellites. Because of this, the majority of work on geometric properties of satellite data has been expended on LANDSAT. Interest in the Skylab conical scanner data has declined since the termination of the Skylab project.

Work on LANDSAT imagery has been mostly concerned with single scene processing, with some attempts at strip and block triangulation.

Bahr (1,2) used LANDSAT and NIMBUS imagery to compare accuracies achieved by using a conformal transformation, second order polynomials, the collinearity condition, and linear least squares prediction.

Borgeson ( 4 ) reported on accuracy tests of bulk corrected images from the EROS data center, using 3,4,5 and 6 parameter transformations to check residual deforamtion left after bulk processing of the imagery.

Rifman et. al.(5,22) studied the use of a Kalman-filter-type estimator for registration of images from LANDSAT 1 and 2, as well as for registration of images from the same sensor.

Derouchie ( 6 ) used a strip of 11 images segments to study control densitites necessary for various accuracy levels. His conclusion was that the optimum spacing of control was every 100 mirror sweeps, or 600 image lines.

Little use has been made of overlapping satellite imagery. Welch and Lo ( 23) report on the use of a 1 micrometer parallax bar combined with a Bausch and Lomb Zoom 70 Stereoscope to obtain elevation differences. Up to nine control points were read in each model, then a polynomial was used to correct for systematic errors. Due to the small scale and low base/height ratio of the imagery, accuracies of only 200 to 300 meters were obtained.

The Skylab S-192 scanner, with its conical scan pattern, presented special geometric problems. Murphrey, et. al. ( 18) published a paper explaining the geometry of the scanner and giving a method for geometric correction of the data. The suggestion was to use the orbital parameters of the satellite in collinearity equations to determine a fifth degree polynomial to transform the image space into object space. This polynomial is used to transform a dense grid of image points, then the remaing points are determined by linear interpolation due to economic considerations. No predictions or checks were made of accuracy achieved.

Malhotra(16,17) conducted accuracy tests on the Skylab scanner imagery. The first phase of his work involved using a parametric model and obtained accuracies of 4 pixels, or about 300 meters. Another phase involved testing the accuracy of generated film images using an affine transformation to test for residual distortions. Accuracies ranged from 105 to 250 meters.

## 4. APPLICATION TO AIRCRAFT DATA

Little work is presently being done on aircraft data, due to the widespread use of LANDSAT imagery.

At Purdue University, the research has followed the early work of Baker and Mikhail ( 3 ). Ethridge and Mikhail(9,10,11) investigated the accuracy of various single strip rectification methods, including the collinearity, piecewise polynomials, weighted mean, moving average, meshwise linear interpolation, and Gauss-Markov. After testing all methods on four data sets, Analysis of Variance (Anova) and Neuman-Keuls statistical testing procedures were used to conclude that there was no statistically significant difference between the results of the best five methods, with only the meshwise linear interpolation being significantly worse. When the methods were ranked in terms of their restitution results the Gauss-Markov was best, collinearity and piecewise polynomial were second, the weighted mean was fourth, and moving averages fifth. Division of the strips into sections when using the parametric methods was shown to have a significant effect. Consideration of other factors involved, such as computational economy and control requirements, led to the conclusion that the piecewise polynomial was the optimum method.

Ethridge also investigated the use of sidelapping flight lines in a block adjustment procedure. Since no real data was available, randomly perturbed and unperturbed simulated data was used. Two algorithms were used in the tests, one a rigorous simultaneous solution while the other involved using the control points to solve for the orientation parameters, then obtaining pass point coordinates by intersections. The resection-intersection method gave results nearly equivalent to those of the rigorous simulatanous method.

McGlone, Mikhail, and Baker(14,15)reported on futher tests with single strip methods, comparing the piecewise polynomial, weighted mean, and Gauss-Markov methods. The piecewise polynomial method using multiple sections and second order polynomials was shown to be the optimum method. Further comparison tests run on the first and second order Gauss-Markov methods showed in general no significant difference between the two, but with the second order tending to be slightly worse.

Ebner and Hössler ( 8 ) studied the use of second order Gauss-Markov processes, using simulated data. It was concluded that redundant control within an image line did not improve rectification accuracy and that the control distribution could be random as long as the bridging distances were not too great. It was also concluded that the correlation time parameter of the modelling process could be chosen as infinity with no effect on the results.

## 5. ADJUSTMENT OF MULTISERIES DATA

Masu and Anderson(20,21)reported on the development of a multiseries adjustment procedure. This involved the adjustment of photography of various scales along with aircraft and spacecraft scanner data in sequential and simultaneous procedures, using tie points selected on the images. Digital tie point selection between the various data sets is also possible. Tests with simulated data showed a 16 to 20 percent improvement over the direct adjustment of each image separately. Tests with real data were less conclusive but did show some improvement.

Testswere also conducted on the block adjustment of sidelapping data. It was shown that planimetric accuracy is increased by having multiple ray intersections and that elevations can be obtained, although not of sufficient accuracy in this case to use for pixel elevation assignment for geometric processing. For three strips, divided into three sections each, the RMSE in x was 15.4 meters (2.0 pixels), in Y 13.3 meters (1.74 pixels), and in Z 34.0 meters (4.46 pixels). Division of the strips into sections again increased the accuracy. Calculation of covariance information for the parameters allowed the assessment of correlations between the orientation parameters. The $\omega$ orientation angle was recoverable using multiple strips, while the $\phi$ was not recoverable, due to lack of relief of the terrain. The inclusion of $\omega$ increased the accuracy of the adjustment.

Nasu (19,20) studied the positioning of thermal IR scanner data using a prametric orientation model. He reported residual errors at the ground control points of 3 to 4 pixels in a test on a volcanic area with large relief differences.

Table 1

Restitution Results from Spacecraft Data

| Investigator | data | method | number of control pts. | RMSE, Y pixels | RMSE, Y pixels |
|---|---|---|---|---|---|
| Bähr | LANDSAT | 4-par | 234 | 2.71 | 4.52 |
| 1976 | bulk image | 2 order poly | 7 | 1.15 | 1.11 |
| | | | 9 | 0.68 | 1.15 |
| | | | 13 | 0.60 | 1.02 |
| | | | 40 | 0.61 | 0.89 |
| | | | 234 | 0.54 | 0.83 |
| | | L.S. filtering after 4-par. | 40 | 0.56 | 0.87 |
| | | L.S. filtering after poly. | 40 | 0.53 | 0.78 |
| | NIMBUS-3 | col. | 67 | 0.68 | 0.80 |
| | | approx.method | 67 | 0.89 | 0.73 |
| | | col. | 84 | 0.83 | 0.83 |
| | | approx.method | 84 | 0.92 | 0.97 |
| | | col. | 81 | 0.79 | 0.86 |
| | | approx.method | 81 | 0.74 | 0.87 |
| | NIMBUS-4 | col. | 40 | 0.81 | 0.89 |
| | | approx.method | 40 | 1.08 | 1.25 |
| Malhotra, | Skylab | col. | -- | 4.0 | 4.3 |
| 1976 | | col. | -- | 4.0 | 3.7 |
| | | col. | -- | 3.7 | 3.8 |
| | | | | RMSE, XY Meters | |
| Borgeson | LANDSAT | 3 par | 151 | 152 | |
| | System | 4 par | 151 | 130 | |
| 1979 | Corrected | 5 par | 151 | 82 | |
| | | 6 par | 151 | 51 | |
| | LANDSAT | 3 par | 53 | 165 | |
| | Image | 4 par | 53 | 143 | |
| | | 5 par | 53 | 84 | |
| | | 6 par | 53 | 49 | |

Table 2
Restitution Results for Single Coverage Aircraft Data

| Investigator | Data description | Method | RMSE X pixels | RMSE Y pixels | RMSE XY pixels |
|---|---|---|---|---|---|
| Ethridge, 1977 | H=1500m IFOV=.006 rad 1550 lines | col. 1 sec. | 1.57 | 2.03 | 1.80 |
| | | " 2 sec. | 1.51 | 1.68 | 1.59 |
| | | " 3 sec. | 1.42 | 1.36 | 1.39 |
| | | p.poly 1 sec. | 1.58 | 2.01 | 1.79 |
| | | 2 sec. | 1.51 | 1.69 | 1.60 |
| | | 3 sec. | 1.42 | 1.37 | 1.40 |
| | | w. mean | 1.56 | 1.23 | 1.41 |
| | | m. avg. | 1.32 | 2.04 | 1.72 |
| | | mesh. linear | 1.35 | 2.26 | 1.86 |
| | | G. Markov, 1st | 1.18 | 1.44 | 1.32 |
| | H=1500m IFOV=.006 rad 1400 lines | Col. 1 sec. | 2.70 | 2.19 | 2.45 |
| | | 2 " | 2.57 | 1.82 | 2.19 |
| | | 3 " | 2.70 | 1.37 | 2.04 |
| | | p.poly 1 sec. | 2.68 | 2.38 | 2.53 |
| | | 2 " | 2.57 | 2.18 | 2.37 |
| | | 3 " | 2.71 | 1.36 | 2.03 |
| | | w. mean | 3.27 | 1.52 | 2.55 |
| | | M. avg. | 2.74 | 1.95 | 2.38 |
| | | mesh. linear | 2.50 | 2.42 | 2.46 |
| | | G. Markov, 1st | 2.05 | 2.33 | 2.20 |
| | H=900m IFOV=.006 rad 1970 lines | Col 1 sec. | 7.33 | 9.66 | 8.58 |
| | | 2 " | 3.69 | 5.17 | 4.49 |
| | | 3 " | 2.89 | 3.08 | 2.99 |
| | | p.poly 1 sec. | 7.33 | 8.71 | 8.05 |
| | | 2 " | 3.66 | 4.74 | 4.24 |
| | | 3 " | 2.89 | 3.15 | 3.02 |
| | | w. mean | 3.05 | 4.44 | 3.81 |
| | | m. avg. | 2.62 | 3.91 | 3.33 |
| | | mesh. linear | 4.35 | 4.82 | 4.59 |
| | | G. Markov, 1st | 2.43 | 2.80 | 2.62 |
| | H=900m IFOV=.006 rad 2700 lines | Col 1 sec. | 4.10 | 4.24 | 3.90 |
| | | 2 " | 4.23 | 3.76 | 3.34 |
| | | 3 " | 4.16 | 4.01 | 3.63 |
| | | p.poly 1 sec. | 4.09 | 4.32 | 4.21 |
| | | 2 " | 4.18 | 3.16 | 3.71 |
| | | 3 " | 3.83 | 3.10 | 3.49 |
| | | w. mean | 3.75 | 2.91 | 3.36 |
| | | m. avg. | 5.33 | 3.58 | 4.54 |
| | | mesh. linear | 4.23 | 7.65 | 6.18 |
| | | G. Markov 1st | 3.66 | 3.77 | 3.72 |
| McGlone, Mikhail, Baker 1980 | H=3050m IFOV=0025 rad 1450 lines | p.poly 1 sec 1 order | 2.76 | 4.76 | 4.14 |
| | | 1 " 2 " | 2.72 | 1.91 | 2.35 |
| | | 2 " 1 " | 2.82 | 2.49 | 2.66 |
| | | 2 " 2 " | 2.23 | 1.74 | 2.00 |
| | | 3 " 1 " | 2.22 | 1.98 | 2.10 |
| | | 3 " 2 " | 2.06 | 1.89 | 1.98 |
| | | w. mean | 3.34 | 1.90 | 2.72 |
| | | G. Markov 1 order | 1.75 | 5.47 | 4.06 |
| | | 2 " | 3.80 | 11.20 | 8.36 |
| | H=3050m | p.poly 1 sec 1 order | 2.14 | 3.85 | 3.11 |

Table 2 (Cont'd)

Restitution Results for Single Coverage Aircraft Data

| Investigator | Data description | Method | RMSE X pixels | RMSE Y pixels | RMSE XY pixels |
|---|---|---|---|---|---|
| | IFOV=.0025 rad | 1 " 2 " | 2.14 | 3.79 | 3.08 |
| | 1450 lines | 2 " 1 " | 2.11 | 3.78 | 3.06 |
| | | 2 " 2 " | 1.57 | 3.39 | 2.64 |
| | | 3 " 1 " | 1.86 | 3.63 | 2.88 |
| | | 3 " 2 " | 1.69 | 3.59 | 2.75 |
| | | w. mean | 3.28 | 3.85 | 3.58 |
| | | G.Markov 1 order | 1.13 | 6.63 | 4.75 |
| | | 2 " | 1.18 | 7.13 | 5.11 |
| | h=3050 m | p. poly 1 sec 1 order | 2.12 | 5.33 | 4.05 |
| | IFOV=.0025 rad | 1 " 2 " | 1.31 | 5.38 | 3.92 |
| | 1450 lines | 2 " 1 " | 1.43 | 5.41 | 3.96 |
| | | 2 " 2 " | 1.28 | 5.26 | 3.83 |
| | | 3 " 1 " | 1.42 | 5.21 | 3.82 |
| | | 3 " 2 " | 1.08 | 7.43 | 5.31 |
| | | w. mean | 2.80 | 4.17 | 3.55 |
| | | G.Markov 1 order | 1.03 | 10.48 | 7.45 |
| | | 2 " | 1.67 | 10.11 | 7.25 |
| | h=1500 m | G.Markov 1 order | 1.27 | 1.32 | 1.30 |
| | IFOV=.006 rad | 2 " | 1.33 | 1.49 | 1.42 |
| | h=1500 m | G.Markov 1 order | 3.26 | 2.34 | 2.83 |
| | IFOV=.006 rad | 2 " | 3.86 | 2.53 | 3.26 |
| | h= 900 m | G.Markov 1 order | 0.90 | 2.10 | 1.62 |
| | IFOV=.006 rad | 2 " | 1.64 | 2.72 | 2.25 |
| | h= 900 m | G.Markov 1 order | 1.99 | 1.80 | 1.90 |
| | IFOV=.006 rad | 2 " | 2.15 | 5.95 | 4.47 |
| | h= 900 m | G.Markov 1 order | 3.16 | 2.26 | 2.75 |
| | IFOV=.066 rad | 2 " | 3.30 | 2.28 | 2.94 |
| | h= 900 m | G.Markov 1 order | 6.64 | 3.77 | 5.40 |
| | IFOV=.006 rad | 2 " | 14.46 | 4.76 | 10.76 |

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